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ABSTRACT

Hypertext researchers and designers contend that the hypertext information structures may reflect the semantic structures of human memory. Further, they believe that mapping the semantic structure of an expert onto hypertext information structure and explicitly illustrating that structure in the hypertext will result in improved comprehension because the knowledge structures of the users will reflect the knowledge structures of the expert to a greater degree. (Structural knowledge is defined as the knowledge of how concepts within a domain are interrelated.) This paper reviews techniques for ascertaining an expert's knowledge structure and mapping it onto hypertext. It then reviews the results of three studies that assess the effects of different methods for explicitly mapping expert knowledge structures onto hypertext on the acquisition of structural knowledge by the learners. The studies show that depicting knowledge structures in the form of a graphical browser or by making explicit the structural nature of the links during traversal does not improve learners' acquisition of structural knowledge. However, when assigned the task of generating a semantic network following browsing, structural knowledge acquisition improved significantly. It is the assigned processing task and goals for learning while interacting with a hypertext that appears to most significantly determine the effects of its use on learners' knowledge structures. (27 references) (Author/BBM)

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Acquiring Structural Knowledge from Semantically Structured Hypertext

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Acquiring Structural Knowledge from Semantically Structured Hypertext

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Abstract

Hypertext researchers and designers contend that the hypertext information structures may reflect the semantic structures of human memory. Further, they believe that mapping the semantic structure of an expert onto hypertext information structure and explicitly illustrating that structure in the hypertext will result in improved comprehension because the knowledge structures of the users will reflect the knowledge structures of the expert to a greater degree (Jonassen, 1990, 1991b). This reviews techniques for ascertaining an expert's knowledge structure and mapping it onto hypertext. It then reviews the results of three studies that assess the effects of different methods for explicitly mapping expert knowledge structures onto hypertext on the acquisition of structural knowledge in the learners. The studies show that depicting knowledge structures in the form of a graphical browser or by making explicit the structural nature of the links during traversal does not improve learners' acquisition of structural knowledge. However, when assigned the task of generating a semantic network following browsing, structural knowledge acquisition improved significantly. It is theassigned processing task and goals for learning while `interacting with a hypertext that appears to most significantly determine the effects of its use on learners' knowledge structures.

INTRODUCTION

Associative Hypertext Structures

Hypertext researchers have recently asserted that hypertext mimics the associative networks of human memory (Fiderio, 1988; Jonassen, 1990, 1991a, 1991b). Bush (1945), who is credited with developing the first prototype hypertext system, observed that ideas result from "the association of thoughts, in accordance with some intricate web of trails carried by cells of the brain". This observation and the continued development of associative network theory have provided a conceptual foundation for the development of hypertexts.

Hypertext, like other technologies such as databases and expert systems, is a knowledge-based system. That is, subject content is stored in a knowledge base which is structured by a particular *data model*, which defines the organization of the information contained in the knowledge base. This organization, in turn, defines the logical relationships between the content units in the knowledge base. The logic in each type of data model varies with the kinds of relationships that comprise it. A hypertext engine, on the other hand, is associative. That is, it is based upon an associative network of ideas. Links may be defined by an open set of associations, so hypertext structures may take on a variety of forms. Therefore, the structure of any hypertext may emulate the logical structures of a variety of instructional designs or functions (Jonassen, 1991b).

The belief that hypertext can mimic human associative networks implies that an appropriate method for structuring hypertext is to mirror the semantic network of an experienced or knowledgeable performer or expert. Semantic networks are rooted in schema theory (Rumelhart & Ortony, 1977). Personal knowledge is stored in information packets or *schemas* that comprise our mental constructs for ideas. Schemas have attributes, which they share with other schemas. Each schema that we construct represents a mini-framework in which to interrelate elements or attributes of information about a topic into a single conceptual unit (Norman, Gentner, & Stevens, 1976). These mini-frameworks are organized by the individual into a larger network of interrelated constructs known as a semantic network. These networks are composed of nodes (representations of schemas) and ordered labelled relationships that define the propositional relationships between them (Norman, Gentner & Stevens, 1976).

The general hypotheses for these studies is that mapping the semantic network of an expert or knowledgeable person onto the structure of a hypertext will contribute to the development of the learners' knowledge structures while using the hypertext to learn.

Learning consists of building new knowledge structures by assimilating environmental information and constructing new nodes that describe and interrelate them with existing nodes and with each other (Norman, 1976). The interrelated knowledge reflected in semantic networks enables humans to combine ideas, infer, extrapolate or otherwise reason with the information. Learning requires the formation of links between existing knowledge and new knowledge in order to comprehend information from the environment. Learning therefore may be conceived of as a reorganization of the learner's knowledge structure that results from the learner's interactions with the environment. However, learning is also influenced by intentional instruction. Research has shown that as a result of teaching, learners' knowledge structures more closely resemble the instructor's (Shavelson, 1974; Thro, 1978), that is, learners acquire the teachers knowledge structure, which in turn improves comprehension. So, learning is the linking of new information with exisiting knowlege, a process which is influenced by the mapping of the teacher's or expert's subject matter knowledge onto the learner's knowledge structure. This conception provides the rationale for mapping the expert's knowledge structure onto learning environments, such as hypertext.

Hypertext engines or structures can be designed to reflect the semantic structure of a subject matter expert. The assumption for doing so is, "if the node-link structure of the hypertext reflects the semantic structure of the expert, the expert's knowledge structure may be more effectively mapped onto the novice browser, thereby improving comprehension." This is the assumption that has been investigated in the studies described below.

EXPERIMENT 1

The most direct way to map the expert's semantic structure onto a hypertext is to use the expert's semantic map as a graphical browser in the hypertext. Graphical browsers are maps or graphical listings of available nodes in a hypertext. They represent a graphical interface between the user and a hypertext that is designed to reduce navigation problems within the hypertext (Jonassen, 1988). Getting lost in a large web of hypertext nodes and links is a commonly reported problem among hypertext users, so graphical browsers are used to provide a spatial orientation to the available nodes in a hypertext. When arranging the nodes in a graphical browser according to an expert's semantic map, the hypertext is explicitly conveying the organization of ideas in the expert's knowledge structure. So, while navigating through a hypertext, the user is in effect navigating through the expert's knowledge structure. The research questions in this study focus on the extent to which the semantic structure illustrated in graphical browsers actually maps onto the user's knowledge structure. To what extent will the user model or replicate that structure in their own knowledge representations?

Method

Sample

This study involved undergraduate pre-service teachers in a teacher education program

Instruments

In order to assess the effects of semantically structured hypertext on learner's knowledge structures, it was necessary to develop instruments that assessed the learners' *structural knowledge*. Structural knowledge is the knowledge of how concepts within a domain are interrelated (Diekhoff, 1983). Structural knowledge enables learners to form the connections that they need to describe and use scripts or complex schemas. It is a form of conceptual knowledge that mediates the translation of declarative knowledge into procedural knowledge.

In order to assess structural knowledge acquisition following various treatments, we developed three subscales of ten questions each to measure different aspects of structural knowledge: a) relationship proximity judgements, b) semantic relationships, and c) analogies. All of the

structural knowledge test questions were developed to focus on relationships between important concepts contained in the hypertext.

The relationship proximity judgements required that students assign a number between 1 and 9 to each of several pairs of concepts to indicate how strong a relationship they thought existed between the concepts in each pair (Diekhoff, 1983; Schvaneveldt, Durso, Goldsmith, Breen, Cooke, Tucker & DeMaio, 1985; Shavelson, 1974). For example:

_____ information retrieval systems and online documentation

_____ hypertext processing strategies and database

The semantic relationships subscale consisted of multiple choice questions that required students to identify the nature of the relationship between two concepts. These relationships were paraphrased from the hypertext knowledge base. For example:

_____ unstructured hypertext ..... navigating hypertext

a. produces problems in
b. defines the functions of
c. counteracts the effects of
d. enabled by

Finally, the analogies subscale required students to complete 10 analogies consisting of four of the concepts from the hypertext. For example:

_____ accessing information : index :: integrating information : .....

a. links
b. hypermaps
c. idea generator
d. multi-user access

These questions were used to assess structural knowledge acquisition. In order to provide standards for assessment, three authors and researchers in the hypertext field agreed on the answers to each of these questions. In addition to assessing structural knowledge, ten lower-order information-recall questions were developed.

Materials

The hypertext that was used was the HyperCard version (Jonassen, Roebuck & Wang, 1990) of the book *Hypertext / Hypermedia* (Jonassen, 1989a). This hypertext is a browsing system consisting of 240 cards and 1167 links in three stacks supported by bookmarking and limited annotation capabilities. All treatments in all studies contained embedded referential links in the cards. Terms in the text were highlighted, enabling learners to immediately traverse the links. The treatments varied in terms of the types of browsers that were made available and the ways that they depicted structural information. Each of the 75 major concept nodes contained a main "related terms" card, which was the first card accessed when traversing a link to that node. In the control group, this card provided a list of terms that are related to the concept being currently examined. This list provided links but no structural information about the nodes or links. The experimental treatments (described in more detail below) replaced these lists with graphical browsers or retained the lists but overtly communicated the nature of each link when it was being traversed. They were to designed to provide or require the learner to generate explicit structural information about the nodes and links in the hypertext.

In this study, we compared the extent to which users acquire structural knowledge by using a graphical browser vs. a pop-up window mediating each link. Each graphical browser showed the

current node and all nodes linked directly to it and explicitly depicted the nature of the relationship between each of those nodes (see Figure 1 for an example). Each of the icons in the graphical browsers were hot buttons which the learners used to navigate through the hypertext. In order to navigate the hypertext, users would click on any icon to traverse the link to that topic.

In the second experimental treatment, the same nodes related to the current node were presented in list form with no indication of the nature of the relationship between the nodes. In order to traverse a link, users simply clicked on a term. Whenever the user clicked on a term to select it, that is to navigate that link, a window filling 70% of the screen area would pop up. The text in this pop-up window stated the explicit relationship between the node the learner was leaving and the node the learner was going to. So, whenever the student traversed a link between the existing and the target node, a pop-up window stated

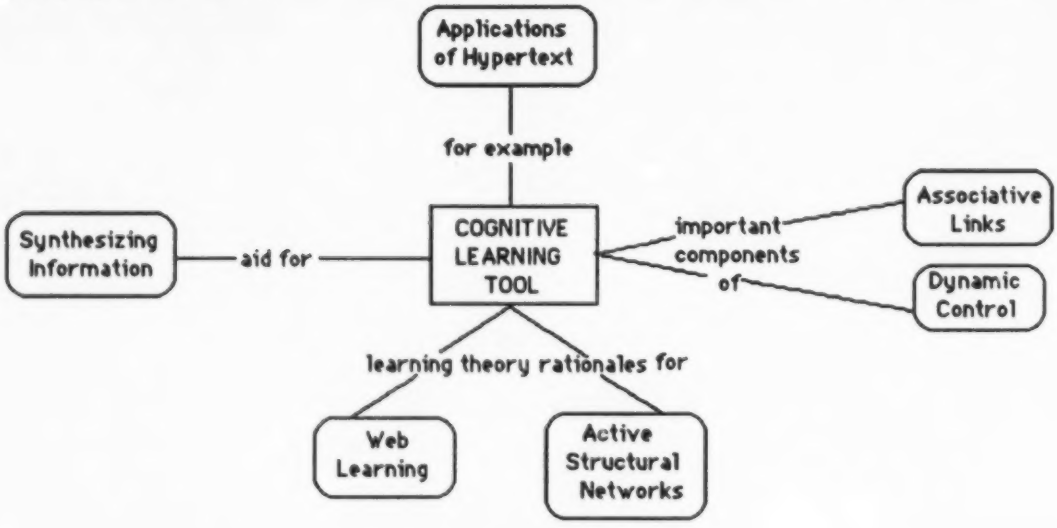

Figure 1
Graphical Browser

explicitly the relationship between the node they were leaving and the one they had selected, providing an explicit statement of structural knowledge.

Both experimental conditions provided structural information to the student. The graphical browser treatment illustrated the organization of information in the hypertext knowledge base, while the pop-up treatment explicitly depicted relationships on a node-by-node basis. In order to navigate the hypertext, the control group students were provided the lists of of related terms with no indication of the nature of the relationship between the nodes. In order to traverse a link, users simply clicked on a term.

Procedure

Students were given the task of learning about an important new instructional technology, hypertext, as an assignment in a pre-service instructional technology course by using a hypertext. In a Macintosh laboratory, students individually interacted with and studied the hypertext in order to acquire as much information about this new technology as possible. A monitoring program was added to the stacks to audit the action and the time allotted to each of the student's actions. Following the interaction, learners were asked to complete the posttests.

Results

The dependent variables in the cognitive domain in this study were the recall, relationship, proximity, and analogy subscales of the posttest. The only independent variable was the version of the treatment administered to each of the subjects. The recall (15 items), relationship (10 items), and

analogy (10 items) subscales were totaled for each subject. The means are presented in Table 1. For the proximity scores, correlation coefficients were calculated for each subject, in which the proximity ratings of the subject were correlated to the proximity ratings of a panel of three experts. The means for these coefficients by group are presented in Table 1.

	Recall	Proximity	Relationship		Proximity		Analogy
	Time	Struc. Cards					
Treatment							
Control	7.8 (2.1)	.295 (.2)	5.4 (2.3)	.572 (.08)	3.0 (1.3)	57.2	27.5
Pop-up	7.4 (2.1)	.333 (.2)	5.6 (1.7)	.616 (.12)	2.7 (1.9)	50.8	45.9
Map	6.6 (1.9)	.320 (.2)	5.0 (2.2)	.583 (.08)	3.1 (1.6)	51.2	53.2

Table 1
Means (Standard Deviations) of Dependent Variables by Group

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Means (Standard Deviations) of Dependent Variables by Group

One way analyses of variance were calculated for each of the four dependent variables. The only dependent variable with even a marginally significant difference was the recall variable ($F(2,93)=2.75$, $p<.07$). A post hoc analysis using a Fisher LSD test showed that the only groups which were significantly different were the control and the map versions, with the control group outperforming the map version ($LSD=1.15$). The map version produced the lowest scores overall.

Time on task was also compared by group. Control group students spent the longest amount of time ($M=57.3$ minutes) while the pop-up group spent only 50.7 minutes. Because of the large standard deviations in the amount of time spent within group, this difference was not significant.

The total number of structurally related cards accessed by students was also calculated. Structural cards were the maps (Map group) or the lists in the other experimental group and the control group. These cards contained the structural information that defined the relationships between the nodes on the knowledge base. The number of structural cards accessed was different between groups ($F(2,93)=3.75$, $p<.05$) while the total number of cards accessed and the total time spent viewing structural cards did not differ significantly. The control group accessed 106 cards while the pop-up and map groups accessed 85 and 92 cards respectively.

The absence of main effects for structural knowledge outcomes did not necessarily mean that no structural coding occurred. In order to assess the role of structural cueing on structural knowledge, regression analyses were calculated. The total umber of cards accessed while reading the hypertext was regressed onto each of the dependent variables. No significant differences occurred. However, when the number of structural cards accessed was regressed on the dependent variables, significant differences occurred. The number of high level structural cards (main map and eight first level maps, eg. Characteristics of Hypertext) that were accessed by students significantly predicted the relationship scores ($F=3.7$, $p=.05$). The number of structural cards accessed also significantly predicted the time spent ($F=5.37$, $p<.05$). The fewer the structural cards that were accessed, the more time that was spent by the students reviewing the knowledge base.

Total time spent interacting with structural cards was also calculated by group. The time spent on structural cards did not significantly regress on any of the dependent variables. The average proximity scores showed an effect of time, although this effect was not significant ($p<.10$).

Discussion

The lack of significant main effects in performance indicates that the information processing required by browsing hypertext overshadowed the design attributes of the interface. The control treatment, which did not provide explicit structural information, produced the highest level of recall. This finding is consistent with research that shows that without cueing or practice, learners tend to recall micropropositions more readily than macropropositions.

There were a number of potential limitations of this study that may have obviated more consistent structural effects. First, the average time spent interacting with this hypertext was less than one hour for virtually all subjects. This short treatment period did not provide adequate exposure to the hypertext or its structural elements. In the follow-up study, incentives will be used to increase the length of the interactions with the hypertext.

In addition to the limited exposure to the hypertext, the lack of hypertext processing strategies (Jonassen, 1989) likely precluded the most effective use of the technology. Hypertext, and the greater control of instruction that it requires, is a novel form of instruction for these learners. The more novel the appearance of the hypertext (ie. mapping version), the more negatively the students reacted to it. A fair evaluation of learning from hypertext can only come from hypertext-literate learners who have developed a useful set of strategies for navigating and integrating information form hypertext.

The novel form of instruction, hypertext, was only exacerbated by the novel structural cues and structural learning outcomes. The explicit provision of structural information is unusual to these students. The requirement to process that information and integrate it into their own knowledge structures was even more novel to them, which negatively affected their performance on the tasks. As evidenced by the floor effect on the analogy questions, these students were not accustomed to higher order, structural knowledge outcomes from instruction. The poor performance of learners on higher order and structural knowledge tasks washed out most of the treatment effects. The relationship test resulted in only one half of the questions answered correctly and less than one third on the analogy tests. Only one half of the paraphrased recall questions were answered correctly. Perhaps verbatim recall questions may have been better answered. This calls into question the ability of learners to acquire knowledge from hypertext in the context of a learning assignment.

A major reason for the lack of main effects in this study as well as the limited potential of hypertext for learning is the lack of generativity in the processing of the information. Wittrock (1974) claimed that meaningful learning results form generative processing in which learners relate new information to their existing knowledge in order to accommodate it to ha they know already. Merely attending to structural cues may not engender generative processing of information. In the next study, the structural cues will be compared with a more generative process in which the students must determine the nature of the link relationships for themselves, rather than being informed by the program.

The post hoc regression analyses provided some evidence that students were in fact attending to some of the structural information. The number of structural cards accessed appeared to predict structural knowledge acquisition in the form of relationship judgements in two different forms. The time spent with the structural cards suggested a relationship between accessing those cards and the level of structural knowledge acquisition. These are weak effects at best, though with longer exposure to the hypertext and the prior acquisition of some hypertext processing strategies should clarify those effects.

Hypertext is an information retrieval technology that may have implications for instruction. If it is to fulfill that potential, then designers must verify methods for facilitating the learning

EXPERIMENT 2

Generative Processing of Structural Information

Perhaps the most significant weakness of the first study was the lack of instructional support provided the learner., given the expectations of learning from the hypertext. Hypertext is a technology that supports information retrieval and search tasks. However, these tasks are not necessarily predictive of learning. The most significant potential problem in learning from hypertext is integration of the information that is browsed into the learner's knowledge structure (Jonassen, 1989a). Learning requires that users not only access information but also interpret it by relating it to prior knowledge, as discussed in the introduction.

Method

Subjects

112 students enrolled in an undergraduate course in instructional technology at a western college participated in this study. The students are enrolled in a teacher certification program.

Instruments and Materials

The instruments used were identical to Experiment 1. However, the treatments were altered. Three treatments were developed for this study using the same HyperCard version (Jonassen, Roebuck & Wang, 1990) of the book *Hypertext / Hypermedia* (Jonassen, 1989) that was used in Experiment 1. The second study attempted to provide additional instructional support by including a more generative form of treatment. Generative learning occurs when learners relate information meaningfully to prior knowledge (Wittrock, 1974). This study included a generative processing treatment. Rather than being told what the nature of the relationship was between the nodes being linked, the learners were required to classify the nature of each link themselves. The pop-up window presented 12 different link types and required the learner to determine which of the link types most accurately depicted the nature of the relationship implied by the link that they were traversing. The user had the option of returning to the previous node or moving forward to see the node they had selected as many times as necessary. Knowledge of results was provided for each selection by the user until the user selected the correct link type.

The control treatment, consisted of embedded referential links in the cardsin addition to the "related terms" nodes attached to the 75 major concepts. The first experimental treatment consisted of the same capabilities with the added feature of a pop-up window mediating each link, as in Experiment 1. Text in the window stated the explicit relationship between the node the learner was leaving and the node the learner was going to whenever the student traversed a link between the existing and the target node (an explicit statement of structural knowledge). The second experimental treatment, the generative treatment, used a pop-up window which asked the student to classify the nature of the relationship between the node they were leaving and the one they were traversing to. Students were provided the option of reviewing the pervious node and the target node in order to help classify the relationship. The first experimental condition provided structural information to the student, and the second required the learner generate his/her own relational information.

Procedure

Students were given the task of learning about an important new instructional technology, hypertext, as an assignment in a pre-service instructional technology course by using a hypertext. In a Macintosh laboratory, students individually interacted with and studied the hypertext in order to acquire as much information about this new technology as possible. A monitoring program was added to the stacks to audit the action and the time allotted to each learner action. Following the study period, learners completed the posttests.

Results

As in the first study, the recall scores of the control group (no structural information provided) were higher than either of the two structural treatments, however, this difference only approached significance ($p=.06$). No differences between relationship, proximity judgements, semantic relationships, or analogy scores occured. As anticipated, recall scores were higher in the control group, but neither structural strategy produced any increase in structural knowledge acquisition.

Treatment	N	Recall	Proximity	Relationship	Analogy
Control	21	5.38 (1.5)	-.144 (.25)	5.10 (1.5)	2.95 (1.3)
Pop-Up	22	4.90 (1.4)	-.088 (.25)	5.73 (1.5)	2.68 (1.6)
Generative	24	4.42 ((1.2)	-.055 (.24)	5.75 (1.6)	2.75 (1.5)

Table 2

In this study, we also assessed the individual difference characteristics, field independence (Hidden Figures Test) and global reading ability/vocabulary (Extended Range Vocabulary Test, both from the Kit of Factor Referenced Cognitive Tests (Ekstrom, French, & Harman, 1976) looking for aptitude-by-treatment interactions. Marginally significant interactions occurred on the recall and relationship variables. In the control and generative treatments, field independent students performed better on the recall task, but they were impeded by the pop-up version. On the semantic relationship task, the opposite occurred. Field independent students in the pop-up version outperformed field dependents while theregression equations for the control and generative groups were flat. No significant interactions occurred on the analogy task. Nor were there any interactions of treatments with vocabulary scores.

EXPERIMENT 3

While instructional tasks are normally thought to be an important predictor of integration of information into knowledge structures (although this was not entirely evident from Experiment 2), probably the most important determinant of learning is the awareness and understanding of the required task or learning outcome. In the previous two studies, it became clear that learners were not certain how to "learn from hypertext". Students in these studies were most familiar with performing specific, convergent, recall-oriented learning tasks. The uncertainty involved in trying to integrate knowledge by focusing on structural relationships when the task was not clear became obvious throughout the course of experimentation. It was also clear from the first two studies that students, based upon their scores on the relationship and analogy tests, were not familiar or competent with structural knowledge tasks. So, the third study provided a more deliberate structural knowledge focus by using semantic networking as a practice and evaluation strategy.

Semantic Networking as an Integrative Strategy

The process of browsing a hypertext models the accretion process in learning (Rumelhart & Norman, 1978). However, a significant problem in learning from hypertext is the integration of what is acquired while browsing into the learner's knowledge structure (Jonassen, 1989b) and the restructuring of thos knowledge structures (Rumelhart & Norman, 1978). Therefore, it may be necessary to provide integration and restructuring activities to browsing in order to ensure learning from hypertext. Semantic networking software may be used as a cognitive learning strategy (Jonassen, 1989) to help learners integrate information from hypertext. Supplementing browsing activity with a semantic networking activity my provide the learner with a tool for integrating information into their knowledge structure. This process of semantic networking also elicits the process of restructuring.

Method

The third study was conducted to assess the role of semantic networking as a cognitive learning strategy to facilitate structural knowledge acquisition. This study assigned a group of the

students the responsibility of constructing a semantic network about the topic of the hypertext following the study period. The other half were told only to study the hypertext to acquire knowledge during the study period.

This third study included a second factor, the type of structural knowledge support. The second factor split both treatment groups into control treatment (no structural cues) and the graphical browser treatment, as in the first study.

Subjects

48 graduate students enrolled courses in instructional technology at a western college participated in this study. These students were enrolled in teacher education and instructional technology programs.

Instruments and Materials

The assessment instruments used in this study were identical to those used in Experiments 1 and 2. Two treatments were developed for this study using the same HyperCard version (Jonassen, Roebuck & Wang, 1990) of the book *Hypertext / Hypermedia* (Jonassen, 1989) that was used in Experiments 1 and 2. The control treatment, consisted of embedded referential links in the cards in addition to the "related terms" nodes attached to the 75 major concepts. Links were presented in list form without any structural information, as in Experiments 1 and 2. The experimental treatment provided users with graphical browser to use for navigation.. Each graphical browser showed the current node and all nodes linked directly to it and explicitly depicted the nature of the relationship between each of those nodes (see Figure 1 for an example). Each of the icons in the graphical browsers were hot buttons which the learners used to navigate through the hypertext. In order to navigate the hypertext, users would click on any icon to traverse the link to that topic.

The second experimental factor investigated the effects of providing a semantic networking learning strategy to the hypertext. In the experimental treatment, we informed learners that they would be required to develop a semantic network about the topic of the hypertext following browsing and studying the hypertext. Learners were provided with with the semantic networking program, Learning Tool (Kozma, 1987). They had perviously learned how to use this tool (see Figure 2 for example).

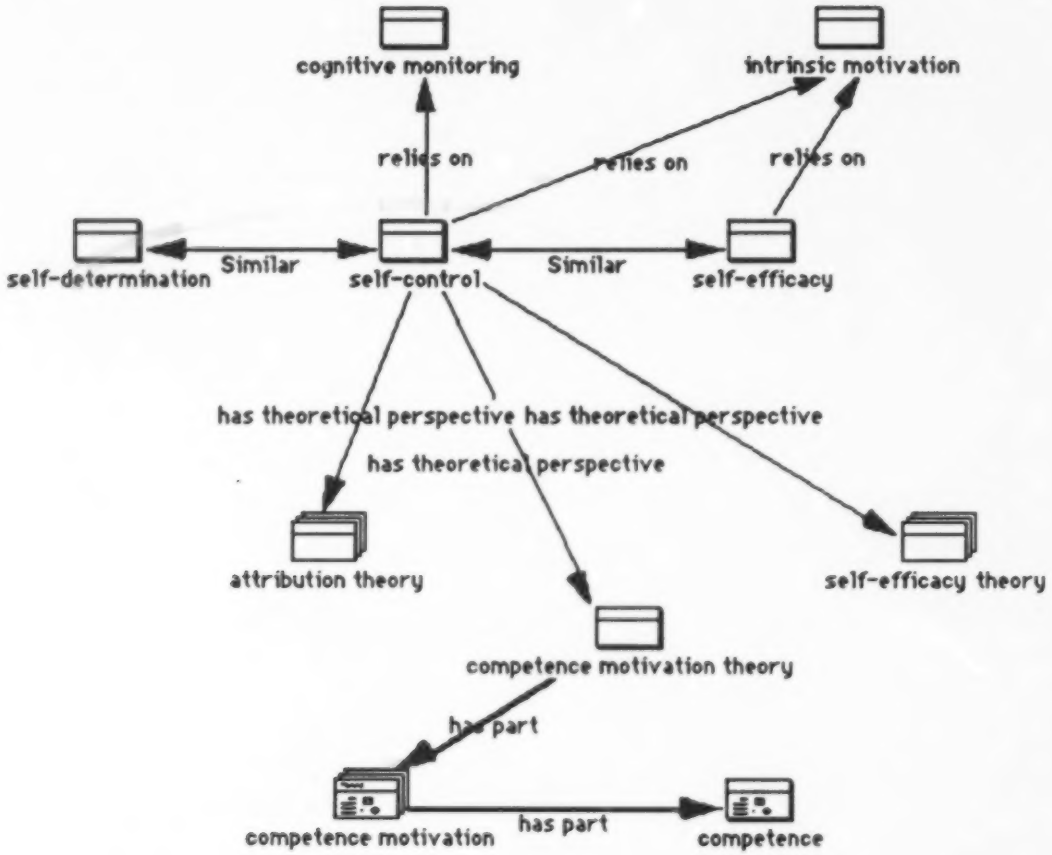

Figure 2

Procedure

Students were given the task of learning about an important new instructional technology, hypertext, as an assignment in their instructional technology course by using a hypertext. In a Macintosh laboratory, students individually interacted with and studied the hypertext in order to acquire as much information about this new technology as possible. A monitoring program was added to the stacks to audit the action and the time allotted to each learner action. The exerimental group was told that they would be responsible for developing a semantic network, however. this activity was ceased after only a few minutes. The treatment was developed to focus their attention on structural information in the hypertext. Learning effects were assessed, as in the other studies, immediately following treatment and before any semantic nets were created, so time-on-task did not differ for the groups.

Results. In the third study, learners who were given the task of creating a semantic network performed significantly better on the relationship judgements task than the two groups instructed only to study the materials , $F=7.82$, $p<.01$. See Table 3 for means. This result indicates that by focusing the learner's attention on structural aspects of the information in the hypertext, structural knowledge acquisition improved significantly.

	Hypertext Version	
Treatment	Control	Graphical Browser
Read Only	4.67(1.3)	5.7 (1.8)
Semantic Net	6.3 (1.7)	6.7 (1.8)

Table 3

Neither the difference between the form of the hypertext or the interaction were significant. No differences in recall scores were found. However, a one factor ANOVA comparing scores between the four treatment groups indicated that the graphical browser/semantic networking group performed significantly better on the analogy subscale, $F=2.77$, $p=.05$. It appears that the visual support of the graphical browser in addition to focusing on structural relationships enhanced the comparisons necessary for completing analogies.

DISCUSSION

Conclusions and discussion from these three studies will be considered together. Several issues regarding the use of hypertext for learning and the enhancement of structural knowledge acquisition emerged from these studies.

Attention to Structural Information

The evidence indicates that to the extent that learners attended to the structural cues provided in the hypertexts, they did acquire some structural knowledge. The post hoc regression analyses showed that students were in fact attending to some of the structural information. The number of structural cards accessed appeared to predict structural knowledge acquisition in the form of relationship judgements in two different forms. The time spent with the structural cards suggested a relationship between accessing those cards and the level of structural knowledge acquisition. These were weak effects, though with longer exposure to the hypertext and the prior acquisition of hypertext processing strategies, these findings may be substantiated.

The most questionable assumption of our hypotheses, based upon the results, is that merely providing structural cues in the user interface will result in structural knowledge acquisition. The fact that control treatments produced the highest level of recall is consistent with research that shows that without cueing or practice, learners tend to recall micropropositions (detail) more readily than macropropositions. The structural information presented clearly impeded the recall of specific facts by the students in the structural knowledge treatments. However, it did not generally result in greater structural knowledge acquisition. The conclusion is obvious -- merely showing learners structural relationships is probably not sufficient to result in structural knowledge encoding. Requiring structural knowledge outcomes in the form of thew semantic networking exercise is able to produce enhanced acquisition of structural knowledge though. That is, getting learners to focus on structural relationships will enhance structural knowledge acquisition, which supports higher order thinking in the form of analogical reasoning.

Cognitive Limitations of Browsing Behavior

Another related and probable reason for no main effects in structural knowledge acquisition is the "mistaken notion concerning hypertext ....that the arbitrary 'webs' of facts in hypertext systems have much semantic significance" (Whalley, 1990, 63). What matters most in learning is the construction of personally relevant knowledge structures. It appears that arbitrarily imposed semantic nets are not adequate to overcome the personal ones or at least not directly mapped onto the learners. It is becoming increasingly obvious that learning from hypertext must rely on externally imposed or mediated learning tasks -- that merely browsing through a knowledge base does not engender deep enough processing to result in meaningful learning.

According to Whalley (1990), the most natural mode of studying hypertext is browsing. The question raised by these studies is the extent to which unconstrained browsing can support learning goals. Hypertexts are obvious information retrieval technologies. However, retrieval of information

is not sufficient by itself to result in meaningful learning. When the goals of accessing information require deeper processing, then deeper processing is more likely to occur. However, simply browsing hypertext is not engaging enough to result in more meaningful learning. It may well be that hypertext is not be very appropriate for highly structured learning tasks, as Duchastel (1990) suggests.

Hypertext Processing Strategies

Students in these studies appeared, as expected, to lack hypertext processing strategies (Jonassen, 1989), which likely precluded the most effective use of the technology. Hypertext, and the greater learner control of instruction that it entails, is a novel form of instruction for these learners. The more novel the appearance of the hypertext (ie. graphical browser version), the more negatively the students reacted to it. A fair evaluation of learning from hypertext can only come from hypertext-literate learners who have developed a useful set of strategies for navigating and integrating information form hypertext. Experiments with learning from hypertext must assume the responsibility of preparing learners to use this relatively novel technology before studying its effects.

Structural Knowledge Acquisition

The novel form of instruction, hypertext, was only exacerbated by the novel structural cues and structural learning outcomes. The explicit provision of structural information was unusual to these students. The requirement to process that information and integrate it into their own knowledge structures was even more novel to them, which negatively affected their performance on the tasks. The poor performance of learners on higher-order, structural knowledge tasks washed out most of the treatment effects. This calls into question the ability of learners to engage in meaningful learning rather than information retrieval from hypertext, especially in the context of a learning assignment. Clearly when students used structural knowledge learning strategies, they can improve their structural knowldge acquisition.

Individual Differences and Learning from Hypertext

As expected, individual differences interacted with learning from hypertext. Field independent processors generally prefer to impose their own structure on information rather than accommodate the structure that is implicit in the materials. In the second study, field independent learners were impeded by the structural information provided in completing the recall task. However, on structural knowledge outcomes, they were the only learners able to successfully use the structural cues to acquire more structural knowledge information than field dependent learners. It is likely that field independent learners are better hypertext processors, especially as the form of the hypertext becomes more referential and less overtly structured.

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